

# Osteoporosis

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Palmer Physical Therapy for Women

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# Osteoporosis

- Disease characterized by low bone mass and micro-architectural deterioration of bone tissue
- Condition of less bone mass resulting from an excess of bone resorption over bone formation
- Bone becomes more fragile, less dense, easier to break
- Osteopenia is a precursor to osteoporosis, indicating the beginning of bone loss
- Osteoporosis is diagnosed when peak bone mass is 75% or less
- Affects approximately 28 million people; 80% are women

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# Osteoporosis

- Bones are dynamic, living substances; always in process of breaking down and rebuilding
- First signs of osteoporosis usually occur in vertebrae, which are trabecular or "soft" bone
- Other bones at risk are hip and wrist bones
- Forward bending activities of the spine cause weakened vertebrae to collapse in the front, resulting in compression fractures and "wedge" deformities; as this occurs in the spine, it causes increased flexion of the spine and increases risk even more
- Common prominent hump in mid back is called thoracic kyphosis, or "Dowager's hump"

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## Osteoporosis



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## Osteoporosis Progression



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## Bone Density Changes



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## Bone Density Changes



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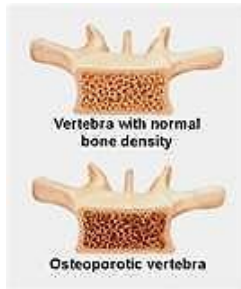
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## Bone Density Changes



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## Osteoporosis-Types

- Type I or Primary = postmenopausal osteoporosis
  - Occurs between ages 51-75
  - Affects 6 times as many women as men
  - Primarily affects trabecular bone
  - Commonly results in vertebral or Colle's fractures at wrists

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## Osteoporosis-Types

- Type 2 = senile or involutional osteoporosis
  - Gradual and age related
  - Mainly occurs in people over 70
  - Affects 2 times as many women as men
  - Mainly affects cortical and trabecular bone, as in femur and vertebral fractures
  - Related to Vitamin D synthesis
  - Type 1 and 2 can occur at the same time in women

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## Osteoporosis-Types

- Secondary Osteoporosis
  - May occur due to medication usage which breaks down bone or impedes bone growth—such as corticosteroids, anticonvulsants, or excessive thyroid medication
  - Can occur due to male hypogonadism, hyperparathyroidism, hyperthyroidism, malignancy, immobilization, RA, COPD, chronic renal failure, heparin therapy, hepatic insufficiency

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## Risk Factors

- Family history of osteoporosis
- Ethnicity--typically Caucasian, Asian, or Hispanic heritage, and slight body build; Black women in the U.S. have a lower prevalence than Whites
- Being post-menopausal
- Early menopause without HRT
- History of smoking (nicotine)
- Excessive alcohol consumption (greater than 2 oz/day)
- Sedentary lifestyle
- Low calcium diet
- Certain medications
- Eating disorders
- Young women with amenorrhea

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## Symptoms

- No symptoms in the early stages of the disease
- Symptoms occurring in the late stages include:
  - Bone pain or tenderness
  - Fractures with little or no trauma
  - Loss of height over time (up to 6 inches)
  - Neck and Low back pain due to fractures of the spinal bones
  - Stooped posture or kyphosis, also known as "dowager's hump"

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## Common Fractures

- Spinal Compression Fractures
  - 50% of women over 65 are affected
  - Can cause pain, deformity and disability which may result in pulmonary, GI and bladder dysfunction
  - Fractures can result in loss of height (1 cm per fracture)
  - Most common sites: T12-L3

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## Vertebral Compression Fracture



Vertebral Compression Fracture

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## Common Fractures

- Hip Fractures
  - 80% of all hip fractures are due to osteoporosis
  - High risk of morbidity or mortality after hip fracture
- Colle's Fractures
  - White females have 15% risk in their lifetimes
  - Most common female fracture until age 75, then hip fracture is most common

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## Hip Fractures



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## Hip Fracture



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## Colles' Fracture



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## Colles' Fracture



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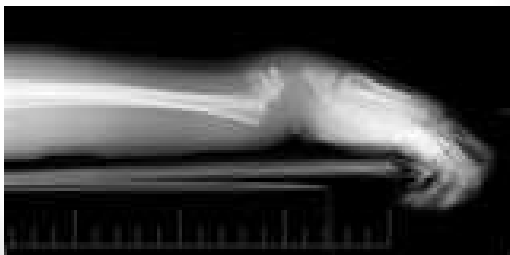
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## Colles' Fracture



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## Surgical Intervention

- Vertebroplasty—used to treat small fractures in the spine, can help prevent weakened vertebrae from fracturing by strengthening bones in the spinal column
- Injection of fast-hardening glue into the fractured or weak areas
- Kyphoplasty—similar procedure using balloons to widen the spaces that need the glue; balloons then removed during the procedure

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## Vertebroplasty



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## Kyphoplasty



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## Kyphoplasty



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## Tests and Monitoring

- Bone mineral density testing=densitometry or DEXA scan
- Measures amount of bone
- Can predict risk for bone fractures in the future
- Quantitative computed tomography (QCT)
- Special type of spine CT
- Used in rare cases
- Spine or hip x-ray
- Simple x-rays not accurate in predicting osteoporosis except in very severe cases
- Blood and urine tests-may indicate whether osteoporosis is due to another medical condition

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## Treatment Goals

- Control pain from the disease
- Slow down or stop bone loss
- Prevent bone fractures with medications that strengthen bone
- Minimize the risk of falls that might cause fractures
- Prevention is most cost effective management
- Best if initiated prior to menopause
- Cannot achieve complete bone retrieval if treatment is begun after bone loss has already occurred

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## Treatment-Medications

- Bisphosphonates—primary drugs to prevent and treat osteoporosis in postmenopausal women; most taken by mouth once/week or once/month with 8 oz water upon waking, and waiting at least 30 minutes before eating, drinking or taking other medications to ensure proper absorption

Alendronate (Fosamax)                      Etidronate (Didonel)  
Zoledronate (Zometa or Reclast)      Ibandronate (Boniva)  
Risedronate (Actonel)

- Side effects: possible GI upset
- Bisphosphonates given intravenously are taken less often

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## Treatment-Medications

- Calcitonin—slows the rate of bone loss and relieves bone pain; comes as nasal spray or injection
- Side effects: nasal irritation from spray form or nausea from injectable form
- Less effective than bisphosphonates
- Raloxifene (Evista)—for prevention and treatment; similar to the breast cancer drug tamoxifen
- Can reduce risk of spinal fractures by 50%; doesn't appear to reduce risk of other fractures
- May have protective effects against heart disease and breast cancer
- Side effect: small risk of blood clots (DVT) or lungs (PE)

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## Treatment-Medications

- Parathyroid Hormone—Teriparatide (Forteo) is approved for postmenopausal women with severe osteoporosis and who are at high risk for fractures
- Administered daily by injection under the skin
- May be utilized at home

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### Recent Evidence

- Wells GA, et al. *Etidronate for the primary and secondary prevention of osteoporotic fractures in postmenopausal women*. Cochrane Database of Systemic Reviews, 2008.
- 11 studies reviewed, with 1248 patients total
- Found significant statistical and clinical benefit in secondary prevention of spinal fx
- No statistically significant reduction in spinal fx for primary prevention
- No statistically significant decrease in any non-spinal, hip or wrist fx in primary or secondary prevention (Silver level evidence for all outcomes)

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### Recent Evidence

- Wells GA, et al. *Risedronate for the primary and secondary prevention of osteoporotic fractures in postmenopausal women*. Cochrane Database of Systemic Reviews, 2008.
- Reviewed 7 trials, with 14,049 women included
- Found significant statistical and clinical benefit in secondary prevention of spinal, non-spinal and hip fx (Gold level of evidence); no secondary prevention benefit for wrist fx (Silver level of evidence)
- No significant reduction in primary prevention of spinal and non-spinal fx (Silver level of evidence)

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### Recent Evidence

- Wells GA, et al. *Alendronate for the primary and secondary prevention of osteoporotic fractures in postmenopausal women*. Cochrane Database of Systemic Reviews, 2008.
- 11 trials representing 12,068 women were reviewed
- Found significant clinical and statistical benefit in reducing spinal, non-spinal, hip and wrist fx in secondary prevention (Gold level evidence)
- No significant results for primary prevention, except for reducing vertebral fx (Gold level evidence)

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### Recent Evidence

- Black D, et al. *Once-a-year infusion reduces osteoporosis fracture risk*. New England Journal of Medicine, 2007.
- Studied 7736 postmenopausal women with osteoporosis over 3 years
- Found a 70% reduced risk of spinal fx and 40% reduced risk of hip fx throughout the 3 year study
- Strong, significant, and consistent effects across all fx types
- In contrast to other studies, women did not experience renal or bone damage with this therapy
- Side effect: atrial fibrillation was small in treatment group (1.3%) and in placebo group (0.5%)
- Not yet approved by US FDA

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### Recent Evidence

- Homik J, et al. *Bisphosphonates for steroid-induced osteoporosis*. Cochrane Database of Systemic Reviews, 1999.
- Review of 13 trials which included 842 patients
- Results: BMD of lumbar spine improved 4.3% more in those taking bisphosphonates (Any type, avg 7.5 mg daily dosage or more); femoral neck BMD improved 2.1% more than non-treatment group
- No difference in spinal fractures between the 2 groups; not enough evidence to say whether bisphosphonates prevent fx

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### Treatment- Estrogen

- Estrogen replacement therapy (ERT)—could prevent or stabilize process of osteoporosis
- Loss of estrogen the most significant risk factor for postmenopausal women
- 75% or greater bone loss in first 20 years is due to estrogen deficiency versus aging
- ERT has positive effects in women over 65; protects against hip fracture between 65-74 years of age; best started at or shortly after menopause and continued for at least 10 years
- In past, ERT thought to be continued indefinitely if for prevention of osteoporosis
- Rarely used anymore to prevent osteoporosis
- ERT not approved to treat a woman who has already been diagnosed

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## Treatment-Diet

- Adequate dietary sources of Calcium (Ca)—equivalent to 3-4, 8 oz glasses of milk/day; most people don't get this and need supplements
- High-Ca foods: cheese, ice cream, low-fat milk, salmon, sardines (with bones), tofu, yogurt, leafy green vegetables
- Ca supplements—women over 65 or postmenopausal should have 1200 to 1500 mg of Ca daily; common side effect is constipation
- Adequate intake of vitamin D: helps the body absorb and utilize Ca better; 800-1000 International units (iu) per day of Vitamin D3
- Adequate intake of protein

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## Recent Evidence

- Shea B, et al. *Calcium supplementation on bone loss in postmenopausal women*. Cochrane Database of Systemic Reviews, 2004.
- Analysis of 15 high quality studies, testing over 1800 postmenopausal women
- BMD testing showed amount of bone lost in women taking Ca supplements for 2 or more years was less than the amount of bone lost in women taking a placebo
- Ca supplements may decrease chances of spine fractures, but it is not known whether it decreases non-spinal fractures
- Side effects: Not analyzed in the review, but stomach upset and constipation may occur

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## Recent Evidence

- Avenell A, et al. *Vitamin D and vitamin D analogues for preventing fractures associated with involutional and postmenopausal osteoporosis*. Cochrane Database of Systemic Reviews 2009.
- Review of 45 trials with 84,585 participants
- Found that taking Vit D alone is unlikely to prevent fracture; Vit D taken with Ca supplements does appear to reduce hip fracture risk in people living in institutional care
- Risks are small, though people with kidney stones, kidney disease or high blood calcium should seek medical advice before taking these supplements

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### Recent Evidence

- Tucker K, et al. *Cola consumption may lower BMD in postmenopausal women*. American Journal of Clinical Nutrition, 2006.
- Framingham Osteoporosis Study of 1413 women and 1125 men, average age 60
- Cola intake linked with significantly lower BMD at the hip, not the spine; found in women, but not men; similar findings for diet and decaffeinated colas, to lesser extent
- Total phosphorus intake not significantly higher in daily consumers vs non-consumers; but decreased Ca-phosphorus ratio in consumers
- Found that a diet low in Ca and high in phosphorus may promote bone loss

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### Recent Evidence

- Homik J, et al. *Calcium and vitamin D for corticosteroid-induced osteoporosis*. Cochrane Database of Systemic Reviews, 1998.
- Review of 5 trials, including 742 subjects; trials compared Ca/Vit D to Ca alone or placebo in patients taking systemic corticosteroids over 2 years
- Found that BMD of the lumbar spine and the forearm of patients taking Ca/Vit D improved more than patients without treatment
- No difference in the number of fx
- Authors concluded that due to low toxicity and low cost, all patients on corticosteroid therapy should receive prophylactic Ca/Vit D therapy

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### Treatment-Lifestyle Changes

- Quit smoking, if you smoke
- Limit alcohol intake—alcohol can damage bones, putting you at risk for falls and fractures
- Prevent falls—
  - § Avoid sedating medications
  - § Remove household hazards like loose rugs or floor clutter
  - § Maintain good vision
  - § Utilize grab bars in bathroom, hand rails on stairs, etc.
  - § Wear proper shoes
  - § Use assistive device if you have one

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## Interventions

- Critical element to managing osteopenia/osteoporosis is exercise and appropriate physical therapy
- Especially need to address postural dysfunction and poor body mechanics
- Avoid spinal flexion positions and activities
- Exercises to stretch tight anterior muscles (flexors) and strengthen weak posterior muscles (extensors)
- Manual therapy to improve soft tissue and spinal joint mobility
- Orthoses—postural support braces, ready or custom made; usually for those who already have severe spinal deformity; hip protectors for those who do fall

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## Orthosis



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## Orthosis



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## Orthosis



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## Orthosis



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## Hip Protector



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## Exercise—Common Recommendations

- Walking or weight bearing exercise activities (recommend at least 4-5 times/week X 30 min.; may have to start at 5-10 min. with very deconditioned women)
- Resistance exercise with light weights or elastic band can stimulate bone building (recommend 2x/week: start with a weight you can lift with little effort 10 times and do 2 sets; increase reps slowly and increase weight every other week)
- Balance exercise and fall prevention education are very important to reduce risk of fractures and other injuries—remove fall hazards like throw rugs or clutter on the floor, have adequate lighting in the home; work on balance exercise with PT or take a class at local gym

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## Recent Evidence

- Sinaki M, et al. *Postmenopausal spinal osteoporosis: flexion versus extension exercises*. Arch Phys Med Rehabil, 1984.
- Studied 59 postmenopausal women with spinal osteoporosis, ages 49-60
- Found that therapeutic exercises may play a role in treatment of osteoporosis; extension or isometric exercises seemed more appropriate than flexion, due to increased force on the vertebrae with flexion, and increased risk of compression fractures ( even if combined with extension exercise)

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## Recent Evidence

- Bonaiuti D, et al. *Exercise for preventing and treating osteoporosis in postmenopausal women*. Cochrane Database of Systematic Reviews, 2002.
- Reviewed 18 RCT's to examine the effectiveness of exercise therapy in preventing bone loss and fractures in postmenopausal women
- Found exercise therapy (such as aerobics, weight bearing and resistance exercise ), appears to be effective in increasing BMD at the lumbar spine and hip; impact of exercise on BMD at the wrist is unclear
- Based on one study, exercise does not appear to prevent fractures during the first 2 years of exercise in this population

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### Recent Evidence

- Kemmler W, et al. *Long-term four-year exercise has a positive effect on menopausal risk factors: the Erlangen Fitness Osteoporosis Prevention Study*. J Strength Cond Res, 2007.
  - Studied 137 postmenopausal women, ages 48-60 years, with asymptomatic lumbar or hip osteopenia per DEXA
  - Found benefits of a long term multi-purpose exercise program for early-postmenopausal women
  - BMD loss at spine and hip in early menopausal years stabilized
  - Exercise groups demonstrated strength improvements as expected, control only had small strength loss in 4 years
  - Power and strength groups did not significantly differ; power training more effective to maintain BMD of spine and hip
  - Low injury rate; drop out rate not a factor
  - Exercise favorable for menopausal risk factors: increased fat loss and bone maintenance; exercise may be considered as alternative to HRT

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### Exercise--Recent Evidence

- Bennell KL, et al. *Effects of an exercise and manual therapy program on physical impairments, function and quality of life in people with osteoporotic vertebral fracture: a randomized, single-blind controlled pilot trial*. BMC Musculoskelet Disord, 2010
  - Studied 17 postmenopausal women and 3 men, over 50 years old, who had sustained at least one vertebral compression fx in the last 2 years
  - Found 10 week program was effective in reducing pain and improving physical function and back muscle endurance

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### Recent Evidence

- Devereux K, et al. *Effects of a water-based program on women 65 years and over: a randomised controlled trial*. Aust J Physiother, 2005.
  - Studied 50 Australian women, 65 yrs and older, with dx of osteopenia or osteoporosis
  - Found significant improvements in left and right step test performance, indicating better dynamic standing balance; no significant difference re: Falls Efficacy Scale between groups
  - Significant improvements in exercise group with physical function, vitality, social function and mental health domains of the questionnaire—possibly from benefits of increased activity, effect of the water, or the group interaction

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### Recent Evidence

- Maddalozzo G, et al. *Resistance training matches HRT in preventing spinal osteoporosis*. Bone, 2007.
- Study assigned women to one of several groups: resistance training exercise, hormone therapy and resistance training, hormone therapy alone, or control with neither regimen for a year
- Found that women in control group lost an avg of 3.6% BMD at the spine
- Hormone therapy without resistance exercise resulted in reduced BMD loss of 0.66%
- Resistance training 2 days/wk with free weights showed increase of 0.43 %in spinal BMD; utilized squat and deadlift as main forms of resistance exercise
- Hormone therapy with resistance exercise had no additional benefit
- Authors conclude that resistance training can be an effective substitute for HRT in lumbar spine BMD preservation in early stages of menopause

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### Recent Evidence

- Madureira MM, et al. *Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial*. Osteoporos Int, 2007.
- Studied 66 women dx with osteoporosis of lumbar, femoral neck or total femur region
- Found a significant improvement for balance in Group 1; study focused on balance, rather than strength, aerobic or flexibility exercises; significant decrease in rate of falls

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### Recent Evidence

- Sinaki M, et al. *Significant reduction in risk of falls and back pain in osteoporotic-kyphotic women through a Spinal Proprioceptive Extension Dynamic (SPEED) program*. Mayo Clin Proc, 2005.
- Studied 25 women (65 years and older), 12 with osteoporosis-kyphosis of 50-60 degrees, and 13 healthy matched controls without kyphosis
- Found that Group 1 had significantly improved balance and gait, and decreased risk of falls; WKO decreased back pain and improved gait velocity, cadence, support time and swing phase

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## Summary

- Much recent high quality literature available regarding management of postmenopausal and corticosteroid induced osteoporosis
- Bisphosphonates are most effective medications currently in use; can aid in prevention of secondary fx; can increase BMD
- Ca and Vit D supplementation are effective in increasing BMD and prevention of fx; highly recommended for those on corticosteroid therapy
- Exercise is highly important in management of osteopenia/osteoporosis
- Early education and intervention is key

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## Exercise & Eating Disorders

### The Female Athlete Triad

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## The Female Athlete Triad

- Disordered Eating
- Amenorrhea
- Osteoporosis

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## Disordered Eating & Pathogenic Weight Control

- Restrictive eating
- Food Avoidance
- Negative Energy Balance (more calories expended than are coming into the body)
- Taking diet pills or laxatives
- Anorexia or Bulimia

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## Disordered Eating

Can result in:

- Electrolyte imbalance
- Dehydration
- Decreased thermal regulation
- Cardiovascular problems
- Poor healing
- Sudden death

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## Anorexia Nervosa

Characteristics:

- Intense fear of fatness
- Abnormal body image
- Absent or disrupted periods
- Weight loss to less than 85% of normal

Associated Signs:

- Low blood pressure
- Slow heart rate (bradycardia)
- Dry skin and nails
- Hair loss or thinning
- Excessive fine hair on the sides of the face and arms (lanugo)

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## Bulimia Nervosa

Related condition characterized by recurrent bingeing and purging (twice/week or more)

Associated signs:

- Enlarged salivary glands
- Periodontal disease
- Conjunctival bleeding
- Scars on the back of the hand from repetitive, forced vomiting
- Statistics show that about 1:100 women binges and purges to lose weight

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## Amenorrhea

- Primary amenorrhea—condition in which girls do not start their periods by age 16 when the usual sex characteristics are present, or by age 14 if no other sex characteristics are present
- Secondary amenorrhea—condition in which the period is absent or irregular; diagnosed in previously menstruating women when there is an absence of 3 consecutive periods, or less than 2 cycles/year
- Athletic amenorrhea—falls into the second category, and occurs when there is a combination of caloric restriction, excessive exercise, emotional stress, and low body fat

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## Osteoporosis

- Premature loss of bone in pre-menopausal women, with an inadequate formation of bone, or combination of both in this instance
- Low bone mass leading to stress fractures in well-known, but unsolved problem in female athletes
- Until a certain threshold level of exercise is reached, bone formation is stimulated, but at higher intensity training the benefit is lost, and in extreme cases may result in bone loss
- Risk of osteopenia, stress fractures, and scoliosis
- Even higher risk later in life after menopause

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### Recent Evidence

- Braam L, et al. *Factors Affecting Bone Loss in Female Endurance Athletes*. Am J of Sports Med, 2003.
- Studied 115 female endurance athletes, 15-50 years of age
- Results: BMD in lumbar spine remained constant, but BMD in femoral neck decreased significantly after 2 years in all 3 groups; highest decrease in amenorrheic group; Neither Vit K nor estrogen prevented bone loss

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### Recent Evidence

- Mehlenbeck R, et al. *A Pilot Intervention to Increase Calcium Intake in Female Collegiate Athletes*. International Journal of Sport Nutrition and Exercise Metabolism, 2004
- Studied 48 female athletes (soccer, cross country, indoor track and basketball) for 16 weeks of competitive season
- Results: pre-season Ca intake lower than national recommendations, and lower in placebo group compared to supplement group
- Adherence to supplementation was good--70% across training season
- Supplementation boosted total Ca intake to recommended level
- Supplementation didn't influence BMD in this time frame; total body BMD increase significantly by 1.5% in the basketball players only
- Need more study over longer trial time to determine whether Ca supplementation positively influences BMD

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### Female Athlete Triad

- Diagnosed when all 3 conditions coexist: eating disorder, amenorrhea, & osteoporosis
- Occurs more frequently in athletic women, but can occur in non-athletic women and girls also
- True prevalence unknown due to under reporting or being under diagnosed

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## Prevention and Treatment

- Requires a multidisciplinary approach: physicians, dietitians, psychologists, physical therapists, nurses, coaches, athletic trainers, dentists, and family
- Appropriate history taking and education is key to recognition, intervention and prevention
- Counseling and family support may help to determine underlying cause, promote a healthy body image, promote healthy eating, address stress, anxiety, and depression issues  
**addendum: eating disorders questionnaire and body image screen**

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## Recent Evidence

- Elliot D, et al. *Definition and Outcome of a Curriculum to Prevent Disordered Eating and Body-shaping Drug Use*. J of School Health, 2006.
- ATLAS program for male HS athletes= Athletes Training and Learning to Avoid Steroids; shown to reduce alcohol and illicit drug use, prevented anabolic steroid use and improved nutrition behaviors; developed in 1990's
- ATHENA program for female HS athletes=Athletes Targeting Healthy Exercise and Nutrition Alternatives; hypothesis for program development based on risk factors for disordered eating and body-shaping drug use

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## Recent Evidence

- Elliot, et al, 2006
  - Surveyed 1178 female athletes from 13 middle and high schools to establish curriculum
  - Applied curriculum to female athletes from 18 other schools; had 20 experimental and 20 control teams
  - Consisted of 8 scripted, coach-facilitated, peer led program sessions; incorporated in team's usual training
  - ATHENA significantly altered targeted risk factors and reduced ongoing and new use of diet pills, body-shaping drugs and supplements (amphetamines, anabolic steroids, etc.)

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## Summary

- Not a lot of current research available re: female athlete triad
- Likely under reported or under diagnosed
- Are we asking the right questions?
- Are we looking for the signs?
- Are we following through with referral to appropriate other health providers?
- Recognition, intervention and prevention are key

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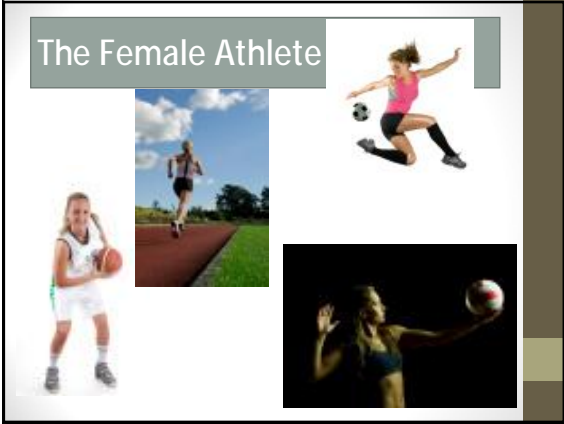
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## The Female Athlete



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## The Female Athlete

- Incidence of Injuries (Myer, et al)
  - Title IX—increased number of women/ girls participating in sports in last 30 years (9 -fold increase in HS and 5-fold increase in collegiate sports)
  - 4-6 fold increased risk of ACL injury in females compared to males playing at similar levels in the same sports
  - OA after ACL injury 10 times greater regardless of the treatment (conservative versus surgical)
  - Estimated 38,000 ACL injuries in female athletes/year (at approximately \$17,000 per injury)
  - Potential loss of entire season of sports participation, possible loss of scholarship funding, lowered academic performance, long-term disability, risk for future OA

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## Incidence of Injuries

- In basketball, HS and collegiate females have 25% increased risk of grade I ankle sprains than males
- Reflex Sympathetic Dystrophy (RSD)—also known as Complex Regional Pain Syndrome (CPRS); 6:1 higher incidence in girls to boys
- Patellofemoral Pain Syndrome (PFPS)—accounts for 5% of all injuries in females; accounts for 25% of all knee injuries in females

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## The Female Athlete

- Physiologic and Anatomical Differences Between Females and Males
  - ✓ Pre-Puberty—girls and boys similar in stature, strength, flexibility, and coordination; similar LE neuromuscular (NM) control
  - ✓ Literature shows no evidence of a difference in ACL injury rates between male and female prepubescent athletes
  - ✓ By age 9-12 in girls, estrogen and progesterone levels start to increase, leading to increase in fatty tissue; VO<sub>2</sub> max, endurance and strength are affected
  - ✓ At puberty, estrogen promotes stronger bones in girls; testosterone produces stronger muscles in boys
  - ✓ After puberty, females may not have a “neuromuscular spurt” to match their increase in growth and development, compared to males; NM imbalances could lead to increased injury risk

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## Hormonal Differences

- Hormonal affects on female physiology
  - ⊗ Strength—by age 16, females have 60% of UE and 75% of LE strength compared to males; women have smaller muscle fiber area and decreased core strength; same capacity for strength gains
  - ⊗ Neuromuscular control—females have slower speed; slower rate of recruitment of hip and knee stabilizers; less strength of contraction
  - ⊗ Aerobic capacity—lower O<sub>2</sub> carrying capacity, lower hemoglobin content; lower blood volume; smaller hearts; lower stroke volume; but athletic training can produce similar increases in aerobic capacity
  - ⊗ Lean body mass—females have a higher percentage of body fat
  - ⊗ Bone mass density
  - ⊗ Joint hypermobility—hyperlaxity of ligaments due to estrogen, progesterone and relaxin
  - ⊗ Breast tissue changes

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### Structural Differences-Lower Quadrant

- Females have a wider pelvis, resulting in greater femoral neck anteversion; can result in increased hip IR
- Q-angle—angle between midline of thigh and midline of patella; 10-15 degrees in females; can predict patellar dysfunction and knee injury in females
- Greater tibial external torsion or rotation in females
- Higher incidence of genu valgum and recurvatum in females
- Smaller, narrower A shaped intercondylar notch at knee; males have a wider U shaped notch
- Smaller diameter of the ACL ligament in females

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### Structural Differences

- Smaller knee joint in females with increased valgus compared to males; leads to increased stress at lateral and patellar compartments; less cartilage thickness and volume contribute to overuse and overloading injuries
- Females also appear to have increased subtalar joint pronation versus males
- “Position of No Return”
  - Forward flexed trunk
  - Hip adduction and internal rotation
  - Knee valgus and decreased knee flexion
  - External tibial rotation
  - Pronated foot

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### Structural Differences-Spine

- Idiopathic scoliosis more common in females
- Lower ratio of upper to lower body size/mass in women
- Joint hypermobility more common in females
- Spondylolysis--stress fracture in pars interarticularis; commonly L4-5; due to repetitive micro trauma
- Males have greater core strength and hip stability

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## Structural Differences-Upper Quadrant

- Breast development—can create postural changes; can lead to cervical, thoracic, shoulder or arm pain/dysfunction; large breasts may result in increased thoracic kyphosis, requiring more supportive sports bra
- Breast pain—under reported; may need extra padding for contact sports; nipple irritation may occur due to vigorous, repetitive abrasion during sports activities
- Joint ligament laxity and soft tissue flexibility are increased
- Increased carrying angle of elbow in females
- Decreased UE strength in females versus males
- Decreased NM control and joint stability in females

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## Neuromuscular Differences

- Myer G, et al. *Rationale and Clinical Techniques for Anterior Cruciate Ligament Injury Prevention Among Female Athletes*. Journal of Athletic Training, 2004.
- Neuromuscular spurt—defined as increased power, strength, and coordination that occur with increasing chronological age and maturation stage in adolescent boys; girls exhibit little change throughout puberty
- No similar correlations found among height, weight, and neuromuscular performance in pubescent females
- No sex differences in vertical jump height noted before age 14; boys significantly increase after that age; girls plateaued around 16 years of age
- Without proper adaptation, musculoskeletal growth during puberty may increase NM imbalances

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## Neuromuscular Imbalances

- Defined as muscle strength or activation patterns that lead to increased joint load
- Females may demonstrate some neuromuscular imbalances that increase LE joint loads during sports
  - Ligament dominance
  - Quadriceps dominance
  - Leg dominance

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## Neuromuscular Imbalances

- Ligament dominance: NM and ligamentous control of the joint is unbalanced, e.g. inability to control dynamic knee valgus when landing and cutting
- Ligaments absorb most ground reaction force instead of muscles during sports maneuvers
- Increased knee medial motion, high valgus moments and high ground reaction forces control direction of motion of LE joints
- Commonly occur in ACL injury mechanisms such as single-leg landing, pivoting, or deceleration

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## Ligament Dominance



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## Ligament Dominance



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## Neuromuscular Imbalances

- **Quadriceps dominance:** imbalance between knee extensor and flexor strength, recruitment, and coordination
  - Females tend to use knee extensors vs their knee flexors
  - React to forward translation of the tibia mainly with activation of quadriceps: males use hamstrings to counteract anterior tibial displacement
  - In running and cutting, women use less knee flexion, increased quadriceps activation, and decreased hamstring activation compared to men
  - Tendency to land with straighter knee during high-intensity tasks; exacerbated by premature quad activation and delayed hamstring activation
  - Landing with knee near full extension is a common mechanism of ACL injury

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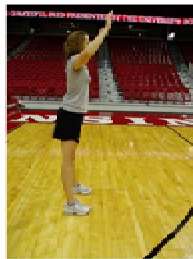
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## Quadriceps Dominance



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## Neuromuscular Imbalances

- **Leg dominance:** the two lower extremities are imbalanced in strength and coordination
  - Side-to-side imbalances in muscular strength, flexibility, joint kinematics, and coordination are predictors of increased injury risk
  - Overreliance on dominant limb places greater stress and torque on that knee; the weaker limb is at risk because musculature cannot properly absorb high forces generated by sports; can increase risk to both limbs

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## Leg Dominance



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## Identification & Treatment

- Ligament Dominance Identification—assess landing from a box (31 cm height) combined with a maximum-effort vertical leap; look for: excessive medial knee motion; knee valgus with femoral adduction; femoral IR in relation to the hip; tibial ER in relation to the femur with or without foot pronation
- Treatment—must first be educated in proper athletic position; functionally stable: starting and finishing position for training exercises
  - ☐ Knees comfortably flexed
  - ☐ Shoulders back
  - ☐ Eyes up
  - ☐ Feet approximately shoulder width apart
  - ☐ Body mass balanced over the balls of the feet
  - ☐ Knees should be over the balls of the feet
  - ☐ Chest over the knees

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## Proper Athletic Ready Position



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## Treatment

- Initial goal to keep the knees apart when landing and err on the side of knee varus positioning
- Instructions should include verbal cues: e.g. “keep knees square; no inward knee motion; keep knees apart; keep hips, knees, and feet aligned straight; soft, silent landings; sit down deep; deep knee bend; land light as a feather”
- Use mirrors or videotape athlete during technique to give visual feedback
- Types of jumps with progressive difficulty—Wall jump, tuck jump, broad jump and hold, 180 degree jump, single-leg hop-and-hold; work from double limb to single limb techniques; lastly add unanticipated cutting movements and more sport specific activity

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## Identification and Treatment

- Quadriceps Dominance Identification—can use isokinetic dynamometry, muscle testing, or simple leg curl or extension machines; hams to quads strength ratios of less than 55 % may indicate a quad dominant athlete; may demonstrate decreased hamstring recruitment patterns with dynamic activity; can also use hop and hold test in single-limb stance with deep knee flexion greater than 90 degrees
- Treatment—emphasize co-contraction of quads and hams to decrease ACL loading; utilize deep knee flexion angles greater than 45 degrees to put quads in ACL agonist position and hams in ACL protective position; Types of jumps—squat jumps, broad jump and hold

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## Identification and Treatment

- Leg Dominance Identification—assess using dynamometer or leg curl or extension machines; difference in strength or power of 20% or more between limbs indicates risk; can assess performance of single limb balanced stance on unbalanced platform to check postural sway (e.g. stabilometer); field exercises like X hops can identify single limb differences
- Treatment—emphasize double leg then single leg movements; equal leg-to-leg strength, balance, and foot placement are stressed; each limb forced to work independently of each other so the other limb can't compensate
- Types of training—tuck jumps, bounding, progression of multiplanar movements, progression to sport specific activity

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## Wall Jump



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## Tuck Jump



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## Broad Jump and Hold



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### 180 Degree Jump



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### Single Leg Hop and Hold



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### Squat Jump



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### X Hops



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### Single Leg Balance



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### Jump, Jump, Vertical Jump



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## Bounding



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## Recent Evidence

- Hewett TE, et al. *Plyometric training in female athletes. Decreased impact forces and increased hamstring torques.* Am J Sports Med, 1996.
  - Studied 11 female HS volleyball athletes, mean age 15 yrs; compared to 11 males similar in height, weight, age, and activity level
  - Authors implied that plyometric training can have positive effect on knee stability and prevention of injury in females; very small sample size; called their program Sportsmetrics plyometrics

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## Recent Evidence

- Hewett TE, et al. *The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study.* Am J Sports Med, 1999.
  - Studied 1263 HS female VB, BB, and soccer players in Cincinnati area; no previous knee injuries
  - Found that the incidence for serious knee injury was 2.4-3.6 times higher in the untrained group than the trained group; indicated that NM training may decrease injury risk in females, possibly due to increased dynamic stability of the knee after training

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### Recent Evidence

- Vescovi JD, et al. *Effects of a plyometric program on vertical landing force and jumping performance in college women.* Phys Ther Sport, 2008.
  - Studied 20 college women, active in intramural basketball, and considered recreationally active (all had at least 3 years experience in organized BB prior)
  - Sample size very small, but found clinically meaningful results in reducing vertical ground reaction forces, and potentially reducing injuries in female athletes
  - [www.Sportsmetrics.net](http://www.Sportsmetrics.net)-- offers further information; CEU programs for certification in injury prevention
  - Sportsmetrics Jump Training by Dr. Walter R. Lowe-available online

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### Recent Evidence

- Myklebust G, et al. *Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons.* Clin J Sport Med, 2003.
  - Studied 2647 female, Norwegian team handball players, mean age 22 years, all with suspected ACL injuries that caused more than 1 wk of missed participation
  - Found a statistically significant reduction in ACL injury incidence between the control season and the 2<sup>nd</sup> intervention season among those completing the program; significant reduction in risk of noncontact ACL injuries; no significant difference between those who did and did not comply with season 2 program; tried to ascertain link between menstrual status and injury, but did not have enough data, and sample was too small; outcomes dependent on player compliance

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### Recent Evidence

- Kovacs EJ, et al. *Effect of training on postural control in figure skaters: a randomized controlled trial of neuromuscular versus basic off-ice training programs.* Clin J Sport Med, 2004.
  - Studied 45 female figure skaters, ages 12-28 years, with avg of 12 years of training/skating
  - Found improved measures of postural control with NM training, which were functionally relevant to figure skating

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### Recent Evidence

- Myer GD, et al. *Neuromuscular training improves performance and lower-extremity biomechanics in female athletes*. J Strength Cond Res, 2005.
  - Studied 53 female HS athletes with previous sports participation in volleyball, basketball or soccer; no current injury, mean age 15.3 years
  - Injury prevention program resulted in improvements in athletic performance with vertical jump height, single leg hop for distance, running speed, 1 rep max squat, 1rep max bench press, knee ROM and knee torques; NM training also improved knee biomechanics during landing from a jump; improvements were statistically and clinically significant (up to 92%)

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### Recent Evidence

- Myer GD, et al. *The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics*. Am J Sports Med, 2006.
  - Studied 23 HS female athletes, volleyball as primary sport, ages 14-17
  - Both effective in reducing measures related to ACL injury and increasing performance measures; balance group had more improvements in single limb strategies
  - Recommended both types of exercise should be included in preseason training and ACL injury prevention programs

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### ACL Injury Prevention Project

- Santa Monica ACL Injury Prevention Project, or PEP program (Prevent Injury, Enhance Performance), 1999
  - Highly specific 15 min training session to replace traditional warm up for sport; designed originally for women's soccer; developed by team of physicians, PT's, ATC's, and coaches; requires little investment in equipment or time
  - Goals—1) avoid vulnerable positions, 2) increase flexibility, 3) increase strength, 4) include plyometric exercises, 5) increase proprioception/ agility
  - Funded for 3 years, with ongoing collection of data on incidence of knee injuries for research in Coast Soccer League
  - Can download copy of program on website:  
<http://www.aclprevent.com/aclprevention.htm>

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### Recent Evidence

- Mandelbaum B, et al. *Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes*. Am J of Sports Med, 2005
  - In 2000, studied 1041 female youth soccer players, ages 14-18: control group consisted of 1905 females, age and skill matched
  - In 2001, studied 844 more for intervention group, and 1913 more in control group
  - Intervention group did program of education, stretching, strengthening, plyometrics, and sports-specific agility drills=PEP program
  - Control group did traditional warm up or sports-specific training only
  - Results: In 2000, there was an 88% decrease, and in 2001, there was a 74% decrease in ACL injury in intervention group vs control

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### Recent Evidence

- Silvers H, Mandelbaum B. *Prevention of anterior cruciate ligament injury in the female athlete*. Br J Sports Med, 2007
  - Great review of previous literature regarding ACL injury
  - Discussed mechanism of injury and risk factors, including anatomy, hormones, environment, biomechanical and neuromuscular factors
  - Reviewed development of the Santa Monica PEP ACL prevention program by authors
  - Compared PEP program with other intervention studies and found many similarities
  - Pointed out need for further future studies regarding fatigue, age of implementation, timing of the intervention programs, and role of fatigue with regard to injury

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### Recent Evidence

- Gilchrist J, et al. *A Randomized Controlled Trial to Prevent Noncontact Anterior Cruciate Ligament Injury in Female Collegiate Soccer Players*. Am J of Sports Med, 2008.
  - Studied 1435 women (852 control, 583 intervention); all Div I soccer players
  - Results: Overall ACL injury rate of intervention group 1.7 times less than control; noncontact ACL injury rate in intervention group was 3.3 times less than control; no ACL injuries during intervention group practices, vs 6 injuries in control; game-related, noncontact ACL injuries was decreased by half in intervention group; intervention group with previous ACL hx significantly less likely to suffer another injury compared to controls

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## Recent Evidence

- Grindstaff T, et al. *Neuromuscular Control Training Programs and Noncontact Anterior Cruciate Ligament Injury Rates in Female Athletes: A Numbers-Needed-to-Treat Analysis*. Journal of Athletic Training, 2006.
- Comprehensive literature review from 1966-2005; selected original research studies (written in English) comparing neuromuscular training programs with control programs to determine number of noncontact ACL injuries per event exposure or hours of playing time; 5 studies met inclusion criteria
- Hewett, et al. Mandelbaum, et al., Myklebust, et al., Olsen, et al., Peterson, et al.
- All 5 studies demonstrated a prophylactic effect due to NM training; gave a Strength of Recommendation Taxonomy level of evidence of 1 and a grade B recommendation supporting use of NM training programs in prevention of ACL injuries in female athletes

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## Summary

- Much recent high quality research available re: LE injury prevention (primarily ACL), and effectiveness of neuromuscular training in females
- Good programs (PEP or Sportsmetrics) available online and ready to use; easy to modify for specific sports or population; may have to be creative in modifying for the less active client
- Not much evidence found re: UE or spine
- Must search for keywords other than "female athlete"; try "knee" or "ACL injury" prevention, "neuromuscular training", etc.

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